

ANSWERS: Hess's Law

$$\begin{aligned}
 1. \Delta_c H^\circ &= \Sigma \Delta_f H^\circ (\text{products}) - \Sigma \Delta_f H^\circ (\text{reactants}) \\
 &= [(5 \times -394) + (6 \times -286)] - [-295] \\
 &= -3686 + 295 \\
 &= -3391 \text{ kJ mol}^{-1}
 \end{aligned}$$

$$\begin{aligned}
 2. \Delta_r H^\circ &= \Sigma \Delta_f H^\circ \text{ products} - \Sigma \Delta_f H^\circ \text{ reactants} \\
 &= (-314) - (-46 + -92) \\
 &= -176 \text{ kJ mol}^{-1}
 \end{aligned}$$

$$\begin{aligned}
 3. \Delta_c H^\circ &= \Sigma \Delta_f H^\circ (\text{products}) - \Sigma \Delta_f H^\circ (\text{reactants}) \\
 &= [(5 \times -394) + (6 \times -286)] - [-295] \\
 &= -3686 + 295 \\
 &= -3391 \text{ kJ mol}^{-1}
 \end{aligned}$$

4. Desired equation is:

$$\begin{aligned}
 &-2\text{EqA} + 3\text{EqB} + 2\text{EqC} - 6\text{Eq4} \\
 &4\text{NH}_3(\text{g}) \rightarrow 2\text{N}_2(\text{g}) + 6\text{H}_2(\text{g}) \quad \Delta_r H = +184 \\
 &6\text{H}_2(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 6\text{H}_2\text{O}(\text{g}) \quad \Delta_r H = -1452 \\
 &2\text{N}_2(\text{g}) + 2\text{O}_2(\text{g}) \rightarrow 4\text{NO}(\text{g}) \quad \Delta_r H = +360 \\
 &6\text{H}_2\text{O}(\text{g}) \rightarrow 6\text{H}_2\text{O}(\text{l}) \quad \Delta_{\text{vap}} H = -246 \\
 &2 \times 92 - 3 \times 484 + 2 \times 180 - 6 \times 41 \\
 &= 184 - 1452 + 360 - 246 \\
 &= -1154 \text{ kJ mol}^{-1} \quad (-1150 \text{ kJ mol}^{-1} \text{ 3 sig fig})
 \end{aligned}$$

$$\begin{aligned}
 5. \Delta_c H^\circ &= \Sigma \Delta_f H^\circ (\text{products}) - \Sigma \Delta_f H^\circ (\text{reactants}) \\
 &= [(10 \times -393) + (11 \times -286)] - (-250) \\
 &= -6826 \text{ kJ mol}^{-1} \text{ or } (-6830 \text{ kJ mol}^{-1})
 \end{aligned}$$

$$\begin{array}{rcl}
 6. \text{(i)} & 3\text{H}_2\text{O} + 2\text{CO}_2 \rightarrow \text{C}_2\text{H}_5\text{OH} + 3\text{O}_2 & +1367 \\
 & 2\text{C} + 2\text{O}_2 \rightarrow 2\text{CO}_2 & -394 \times 2 \text{ (788)} \\
 & \underline{3\text{H}_2 + 1\frac{1}{2}\text{O}_2 \rightarrow 3\text{H}_2\text{O}} & \underline{-286 \times 3 \text{ (858)}} \\
 & \frac{1}{2}\text{O}_2 + 2\text{C} + 3\text{H}_2 \rightarrow \text{C}_2\text{H}_5\text{OH} & -279 \text{ kJ mol}^{-1}
 \end{array}$$

(ii) The enthalpy change would be more positive.

Heat energy is absorbed when converting a liquid to a gas. Therefore if the ethanol formed were in the gaseous state, less energy would be released in its formation / products would have a higher enthalpy.

$$\begin{array}{rcl}
 7. & 2\text{Zn} + 2\text{S} \rightarrow 2\text{ZnS} & 2 \text{ (200)} \\
 & 2\text{Zn} + \text{O}_2 \rightarrow 2\text{ZnO} & 2 \text{ (-348)} \\
 & 2\text{S} + 2\text{O}_2 \rightarrow 2\text{SO}_2 & \underline{2 \text{ (-297)}} \\
 & & -890 \text{ kJ mol}^{-1}
 \end{array}$$

OR

$$\begin{aligned}
 \Delta_r H^\circ &= \Sigma \Delta_f H^\circ \text{ products} - \Sigma \Delta_f H^\circ \text{ reactants} \\
 &= 2(-348) + 2(-297) - 2(-200) \\
 &= -890 \text{ kJ mol}^{-1}
 \end{aligned}$$

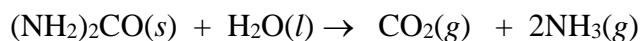
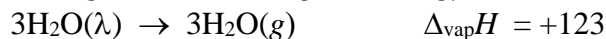
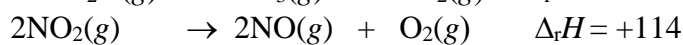
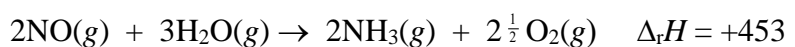
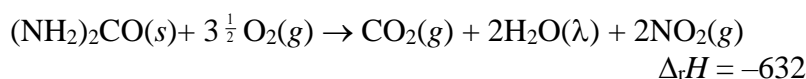
$$\begin{aligned}
 8. \Delta_r H^\circ &= \Sigma \Delta_f H^\circ (\text{products}) - \Sigma \Delta_f H^\circ (\text{reactants}) \\
 -4163 &= 6 \times (-393) + 7 \times (-286) - \Delta_f H^\circ (\text{C}_6\text{H}_{14}, \text{l})
 \end{aligned}$$

$$\Delta_f H^\circ (\text{C}_6\text{H}_{14}, \text{l}) = \{6 \times (-393) + 7 \times (-286)\} + 4163 = (-2358 - 2002) + 4163$$

$$\Delta_f H^\circ(\text{C}_6\text{H}_{14}, \ell) = -197 \text{ kJ mol}^{-1}$$

(could use manipulation of equations – Hess's Law) second set of values apply)

9. Desired Equation = EqA – $\frac{1}{2}$ EqB – 2EqC + 3EqD

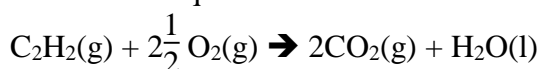


$$\Delta_r H = \Delta_r H (\text{EqA}) - \frac{1}{2} \Delta_r H (\text{EqB}) - 2\Delta_r H (\text{EqC}) + 3\Delta_{\text{vap}} H (\text{EqD})$$

$$= -632 + \frac{1}{2} 906 + 2 \times 57 + 3 \times 41$$

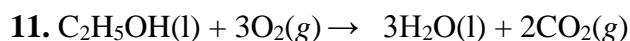
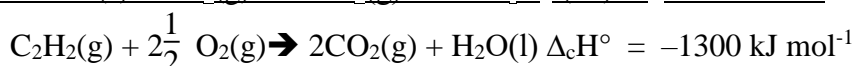
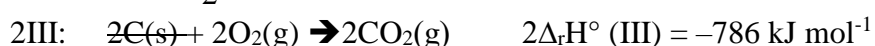
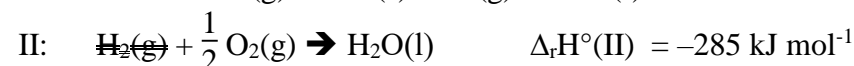
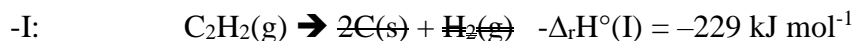
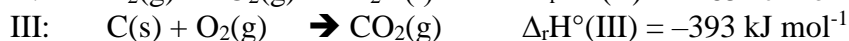
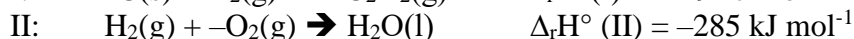
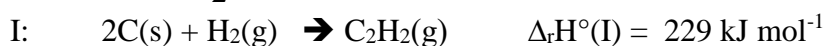
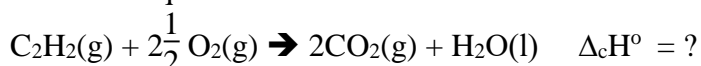
$$= -632 + 453 + 114 + 123 = 58 \text{ kJ mol}^{-1}$$

10. Desired Equation:



$$\begin{aligned} \Delta_c H^\circ &= \sum \Delta_f H^\circ (\text{products}) - \sum \Delta_f H^\circ (\text{reactants}) \\ &= 2\Delta_f H^\circ (\text{CO}_2) + \Delta_f H^\circ (\text{H}_2\text{O}) - \Delta_f H^\circ (\text{C}_2\text{H}_2) - \Delta_f H^\circ (\text{O}_2) \\ &= 2 \times (-393) + (-285) - (+229) - 0 \\ &= -1300 \text{ kJ mol}^{-1} \end{aligned}$$

OR Desired Equation:

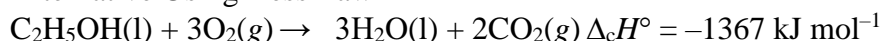


$$3 \times \Delta_f H^\circ (\text{H}_2\text{O}, \text{l}) + 2 \times \Delta_f H^\circ (\text{CO}_2, \text{g}) - \Delta_f H^\circ (\text{C}_2\text{H}_5\text{OH}, \text{l}) = -1367 \text{ kJ}$$

$$\Delta_f H^\circ (\text{C}_2\text{H}_5\text{OH}, \text{l}) = -858 - 788 + 1367$$

$$= -279 \text{ kJ mol}^{-1}$$

Alternative Using Hess Law



hence

